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RESPONSE OF A POLE-SIZE PONDEROSA PINE STAND TO NITROGEN, PHOSPHORUS, AND SULFUR

by

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Abstract

Fertilization with nitrogen alone, nitrogen plus phosphor nitrogen plus sulfur, and nitrogen plus phosphorus plus sulfu increased growth of volume, basal area, and bole area for the first 4 years after application. Application rates were 200 100, and 30 pounds per acre for nitrogen, phosphorus, and s respectively. The effect of sulfur and phosphorus in incre volume and bole area growth was not clear. The treatment all three elements produced the greatest increase in basal

KEYWORDS: Nitrogen fertilizer response, fert (forest tree), phosphorus, sulphur, pole-stage stan

METRIC EQUIVALENTS

1 pound/acre = 1.121 kilograms/hectare
1 acre = 0.405 hectare
1 foot = 0.304 8 meter
1 inch = 2.54 centimeters
1 square foot/acre = 0.229 568 square meter/hectare
1 cubic foot/acre = 0.069 972 cubic meter/hectare
1 mile = 1.61 kilometers

INTRODUCTION

Thinning dense stands of young ponderosa pine (*Pinus ponderosa* Laws.) usually increases diameter and height growth of the remaining trees and raises production of marketable wood under current utilization standards (Barrett 1973). Complete removal of understory vegetation also accelerated growth of young ponderosa pine in one central Oregon study, presumably by increasing the availability of water (and nutrients) to the trees (Barrett 1970).

Several studies show that some ponderosa pine stands will respond to fertilization (Mosher 1960; Wagle and Beasley 1968; Agee and Biswell 1970; Barrett and Youngberg 1970; Cochran 1973, 1977; Youngberg 1975). Much of the increased wood growth seems to result from nitrogen (N), but sulfur (S) and phosphorus (P) may be important on some sites (Will and Youngberg 1978).

This 4-year study was initiated in 1972 to determine how fertilization with N alone and with S and P changes growth of ponderosa pine stands which have been previously thinned.

METHODS

Study Area

The study site is located on the Deschutes National Forest 15 miles[1/] south of Bend, Oregon. Elevation is about 4,000 feet, annual precipitation is approximately 20 inches, and summers are usually dry. Topography in the study area slopes south and west 2 to 17 percent. The soil, a Typic cryandept (Shanahan series) developing on Mazama pumice, has a sandy loam A1 horizon 2 inches thick and a sandy loam AC horizon 21 inches thich overlying an older buried loam (table 1). Predominant understory vegetation consists of bitterbrush (*Purshia tridentata* (Pursh) DC.), needlegrass (*Stipa occidentalis* Thurb. ex Wats.), and fescue (*Festuca idahoensis* Elm.), with some manzanita (*Arctostaphylos patula* Greene) and snowbrush (*Ceanothus velutinus* var. *velutinus* Dougl. ex. Hook).

The area was railroad logged in 1927, and the present stand was 39 years old at breast height (bh) when the study was initiated. The site index (Barrett 1978) varies from 90 to 108 over the study site. The stand was thinned to an overall average spacing of about 14 feet (222 trees per acre) in 1963 and a few scattered overstory remnants were removed in the winter of 1970-71. Saving vigorous appearing, well-formed potential crop trees visibly free of mistletoe had priority over maintaining a uniform spacing in the thinning operation; therefore, tree spacing varies widely over the area (table 2).

Plot Selection and Measurements

Twenty-five 0.4-acre square areas were located to provide 0.1-acre square plots with 33-foot buffer strips. When roads, treeless openings, and stumps

[1/] Metric equivalents are on front cover.

Table 1--*Some properties of the Shanahan soil at the study site on the Deschutes National Forest, Oregon*[1/]

Horizon	Depth	Bulk density	Sand	Silt	Clay	<2 mm gravel	pH	P	B	S	Total N	O.M.[2/]	Extractable cations K	Extractable cations Ca	Extractable cations Mg	Extractable cations Na	C.E.C.[3/]
	Inches	g/cm^3	- - - - Percent- - - - -					- - p/m - -			- Percent -		- - - - - - Meq/100 g - - - - - - -				
A1	0- 2	0.74	71.0	18.4	10.6	3.2	6.2	19	0.25	<0.20	0.13	9.90	0.66	5.3	0.76	0.10	12.0
AC	2-23	.94	68.0	20.0	12.0	2.9	6.6	6	.13	.60	.04	1.54	.53	3.5	.63	.10	10.2

[1/]The hydrometer method was used for the mechanical analysis of the sieved fraction less than 2 mm in size. Chemical analyses were performed by the Oregon State University soil testing laboratory, Corvallis, by its methods (Roberts et al. 1971).

[2/]O.M. = organic matter.

[3/]C.E.C. = cation exchange capacity.

Table 2--*Initial ranges in some stand characteristics for the five 1/10-acre plots randomly assigned to each treatment*

Treatment[1/]	Trees	Volume	Basal area	Bole area[2/]	Average height	Average cylindrical form factor
	Number per acre	Cubic feet per acre	- Square feet per acre -		Feet	
Control	130-320	797-1,816	58.4-124.4	6,209-13,886	36.9-46.5	0.3402-0.3700
N	110-250	668-1,656	48.7-115.9	4,895-12,138	37.9-42.5	.3321- .3594
NP	140-220	738-1,552	62.7- 98.1	6,119-11,784	33.1-42.1	.3429- .3663
NS	150-200	857-1,691	67.4-109.6	7,309-11,769	37.3-42.9	.3389- .3649
NPS	130-340	906-1,615	61.9- 99.6	6,999-11,380	32.7-43.4	.3201- .3720

[1/]N = nitrogen; NP = nitrogen plus phosphorus; NS = nitrogen plus sulfur; NPS = nitrogen plus phosphorus plus sulfur.

[2/]Bole area is the surface area of the bole of the tree with the bark removed. It is an approximation of the cambial surface area along the main tree stem (Lexen 1943).

of overstory removed in 1970-71 were omitted in locating the 0.4-acre areas
all the thinned area was utilized and there was no room t
changes in slope or site in the study design. The
of 458 trees; average diameter and height we
Trees in each 0.1-acre plot were tagged
Diameters at a 1-foot stump and at 4.5
also determined with calipers, diamete
These measurements and Grosenbaugh's (1964) STX program were used to determine pretreatment volumes and bole areas above a 1-foot stump and total height. A modification of one of Brickell's (1970) equations was used in the STX program to determine diameter inside bark at various points along the boles as outlined by Cochran (1976).

Trees were remeasured four growing seasons after treatment; dendrometer readings were retaken from the initial directions for each tree.

Cylindrical form factors (F) were calculated for each tree before and 4 years after treatment; the cubic volume (V) above a 1-foot stump was divided by the product of the basal area at bh (a) and total height (h):

$$F = V/ah$$

Treatments

Each plot was randomly assigned one of five treatments:

Treatment	Amount (lb/acre) and element applied	Form
1 (control)	0	---
2	200 N	urea (46 percent N)
3	200 N, 100 P	urea, triple superphosphate (19.6 percent P)
4	200 N, 30 S	urea, ammonium sulfate (21 percent N, 24 percent S)
5	200 N, 100 P, 30 S	urea, triple superphosphate, ammonium sulfate

The triple superphosphate also contained 12 percent calcium (Ca) and 1 percent S. Application of Ca to the soil does not produce responses from pine seedlings in the greenhouse, and the small amount of S was negligible. Balances of N, P, and S equivalent 200-100-30 pounds per acre were chosen because they appeared to be the most favorable for pine seedling growth in a greenhouse test on a soil derived from Mazama pumice (Youngberg and Dyrness 1965). Fertilizer was applied in November 1972 just before snow began to accumulate.

Statistical Analysis

Growth of volume, bole area, and basal area for the plots was subjected to analysis of covariance with initial basal area as the covariate. The adjusted means for the covariance analysis were combined with multipliers of a set of orthogonal comparisons (determined before treatment) to test these hypotheses:

1. The control grows as much as the average of the rest of the treatments.
2. Growth response from addition of N alone is as good as the average produced by additions of NP, NS, and NPS.
3. Growth response to the NPS treatment is equal to average growth response of the NP and NS treatments.
4. The NS treatment and NP treatments produce the same changes in volume growth.

Height growth and form factor changes were subjected to a standard one-way analysis of variance to test the hypothesis that treatment did not influence height growth or form factor change.

RESULTS AND DISCUSSION

As expected, no tree mortality occurred during the 4-year study. Volume, basal area, and bole area growth were increased significantly by all combinations of fertilizers. Fertilization with N alone caused increases in adjusted treatment means of 34 percent for volume growth, 23 percent for basal area growth, and 20 percent for bole area growth (table 3, fig. 1). Combining S or P with N

Table 3--*Adjusted means of volume, basal area, and bole area growth determined from covariance analysis and treatment means of height growth and form factor change determined from 1-way analysis of variance using plot averages as observations*[1]

Treatment[2]	Adjusted means from covariance analysis			Treatment means	
	Volume growth per year	Basal area growth per year	Bole area growth per year	Height growth per year	Change in form factor
	Cubic feet per acre	- - - - - Square feet per acre - - - - -		Feet	
Control	56.4 a	2.6 a	318.6 a	0.8 a	-0.0127 a
N	75.7 b	3.2 b	383.2 b	1.0 a	-.0050 a
NP	78.0 b	3.5 b c	434.5 b	1.2 a	-.0085 a
NS	88.0 b	3.6 b c	460.1 b	.9 a	-.0031 a
NPS	87.7 b	4.1 b d	481.2 b	.9 a	-.0034 a

[1] Means followed by the letter b are significantly greater than those followed by the letter a, and those followed by the letter d are significantly greater than those followed by the letter c at the 5-percent level of probability.

[2] N = nitrogen; NP = nitrogen plus phosphorus; NS = nitrogen plus sulfur; NPS = nitrogen plus phosphorus plus sulfur.

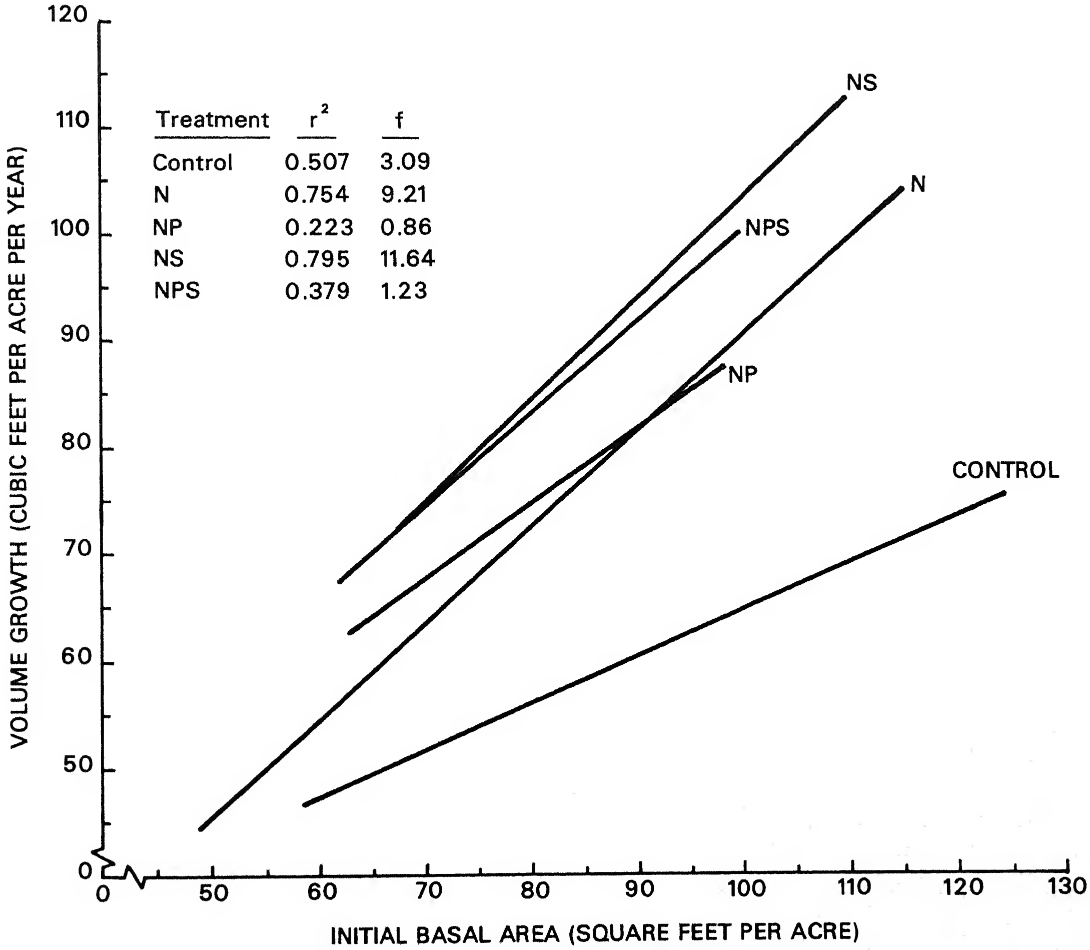

Figure 1.--Individual regressions for volume growth as a function of initial basal area. An F value of 10.13 is necessary for significance at the 5-percent level of probability. The combined regression for all treatments was significant at the 1-percent level of probability.

did not increase volume or bole area growth significantly. The NPS treatment produced significantly greater basal area growth than did the NS or NP treatment. The basal area growth rates produced by the NS and NP treatments tended to be higher than the basal area growth rates produced by N alone but were not quite significant. Bole area growth produced by the NP, NS, and NPS treatments also tended to be higher than bole area growth for the N treatment.

Fertilization did not affect height growth or the change in form factor (table 3). Although the control treatments had the lowest average height growth and the greatest change in form factor, differences did not even tend toward significance.

The increase in basal area growth with the NPS treatment over N alone, combined with a nonsignificant change in volume, height growth, or form factor, is puzzling. Basal areas can be measured precisely, but volumes and form factors depend on assumed taper relationships within bole segments. Also, stem diameters inside bark between bole segments and above bh are determined from dendrometer readings and estimates of bark thickness. Thus, estimates of basal area growth are probably more accurate than estimates of form factor change or volume and bole area growth even though every tree in the study was measured with a dendrometer.

The primary goal of fertilizing stands similar to these is production of more usable volume. Application of P and S along with N at the rates tested here did not prove justifiable; however, this study did not rule out the possible importance of S or P. Will and Youngberg (1978) found that an NPS treatment (200 lb N, 50 lb P, and 100 lb S per acre) on a Shanahan soil produced a slightly greater basal area increment the second 5-year period after treatment than the N, NP, or NS treatments. They also suspected that S increased wood production. There may be a small S effect in this study that the experiment was not sensitive enough to determine. This effect, if real, may be responsible for increasing volume production more than 10 ft^3/acre per year over the N alone treatment (fig. 1).

Published soil N values determined by the same method in other studies (Geist and Strickler 1970, Geist 1974, Tiedemann and Klock 1977, Tiedemann and Berndt 1972) and other results from nonpumice soils (Cochran 1977) indicate that 200 lb N per acre (435 lb urea/acre) will increase growth of many pine stands on nonpumice soils east of the Cascades in Oregon and Washington. Reported soil S and P values from nonpumice areas are generally higher than those found here, but the possible importance of S and P applications in other areas for increasing wood production is hard to evaluate because other soil testing methods were used at times so the results are not comparable.

Geist (1976) found S as well as N is important in increasing forested range production on volcanic ash soils in northeastern Oregon. The demonstrated increase in grass production, coupled with the possible importance of S in wood fiber production, may cause some land managers to apply S along with N to thinned ponderosa pine stands. For S plus N applications, a rate of 30 lb S per acre in the form of ammonium sulfate is suggested. Adding 125 lb of ammonium sulfate per acre will also supply 26 lb of N per acre. The extra 174 lb of N per acre needed for the recommended level can be supplied with 380 lb of urea per acre.

Growth rates of this pole-size stand for the second 4-year period will be measured to see if application of S and P along with N causes a significant increase in usable wood over a longer period. For foresters wishing to fertilize thinned stands now, these results show that 200 lb N per acre will produce a 15- to 45-percent increase in growth of thinned stands on similar soils at least for a 4-year period. These increases in growth will probably last longer than 4 years (Cochran 1977).

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